



NGNGV Reviews

Phase I Engine Research:

Development of a Medium Duty Low NOx CNG Engine

Phase II Vehicle Development:

Development of a Medium Duty Low NOx CNG Vehicle

Washington, DC

July 24, 2003



Phase I Engine Research

The Teleflex*GFI*/GM MY 03 production launch is in progress of the CNG 6.0 L T-610 cargo and passenger vans, and incomplete cab and chassis vehicles up to 12,200 lbs GVWR.

The Phase I Engine Research project (supported by SCAQMD under the NGNGV project project), was an adjunct to the GM T-610 production program, to develop advanced emissions control systems for the 6.0 L CNG engine.

TGFI/GM CNG T-610

MY 03 PRODUCTION

Four Models Certified:

- **Complete Van – Dedicated CNG – CARB SULEV**
- **Complete Van – Bi-fuel CNG/Gasoline ULEV**
- **Incomplete Cutaway Chassis – Dedicated CNG**
- **Incomplete Cutaway Chassis – Bi-fuel CNG/Gasoline**

Specifications:

All vehicles equipped with 6L V8 SI engine, 300 HP on gasoline

Complete box vans 8600lbs and 9600 lbs GVWR, ALVW<8500

Incomplete cutaway 12,200 lbs GVWR

TGFI/GM CNG T-610

MY 03 PRODUCTION

Engine certification of the MY 03 Incomplete CNG vehicles was achieved as follows:

Dedicated CNG – CARB 05 ULEV – 1.0 g/bhp.hr NO_x
EPA ULEV - 1.0 g/bhp.hr NO_x

Bi-fuel CNG - CARB/EPA 04 Option 1 – 1.5 g/bhp.hr Nox

NGNV

Phase I Engine Research

Awarded under the NGNGV Program, supported by AQMD

Objectives

As an adjunct to the production GM T-610 CNG program, develop a low NO_x GM 6.0L CNG medium duty engine which will have NO_x emissions at or below:

- 0.5 g/bhp.hr
- 0.2 g/bhp.hr

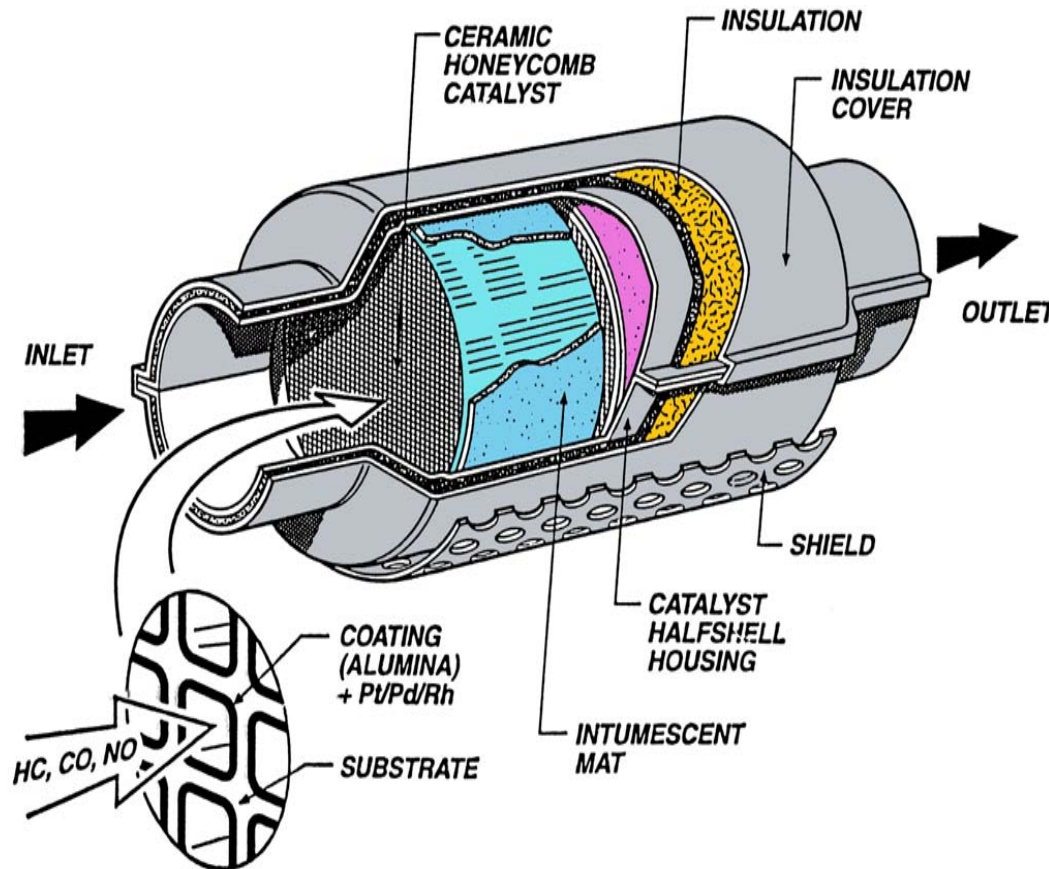
Project Team:



Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications

Layered washcoat architectures to maximize noble metal effectiveness

- **Support materials with high thermal stability**
- **Advanced OSC materials with improved thermal durability**
- **High cell density ceramic or metallic substrates**



Strategies for Advanced Catalyst Design



Advanced Catalyst Options:

- Substrate cell density change – U/F cats – enhanced residence time
- Washcoat technology upgrade – trimetal with low and high Pd – enhanced low temperature performance
- Move existing package closer – enhanced low temperature performance
- Close coupled plus U/F cats, with upgraded substrate cell density change
- Calibration options

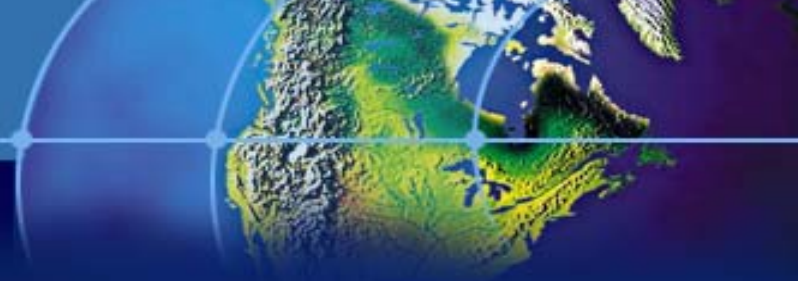
Advanced Catalysts Selected for test program



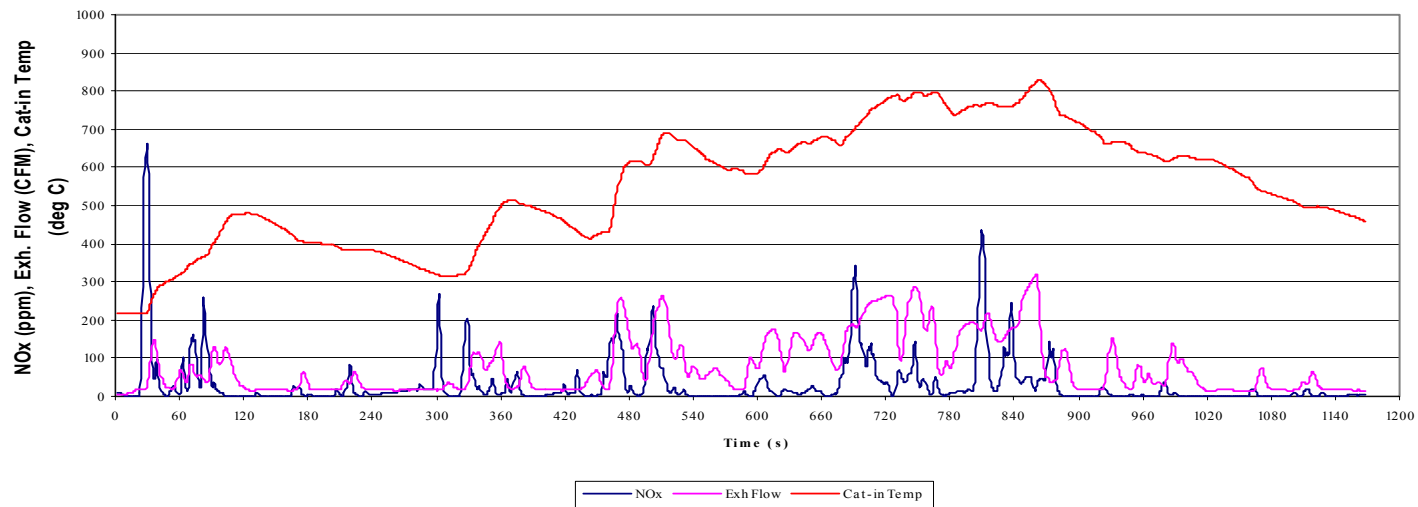
Advanced Catalysts Selected:

- Huntsville, Alabama facility –
600 cpsi/3.5 mil wall NEX 311H1 catalyst technology with
30 g/ft³ Pt/Pd/Rh 3/0/1 (current cats 350 cpsi/5.5 mil wall)
- Nienburg, Germany facility –
600 cpsi/3.5 mil wall OEX-101B catalyst technology with
30 g/ft³ Pt/Pd/Rh 1/2/1
- 600 cpsi/3.5 mil wall OEX-101B with 45 g/ft³ Pt/Pd/Rh
1/2/1

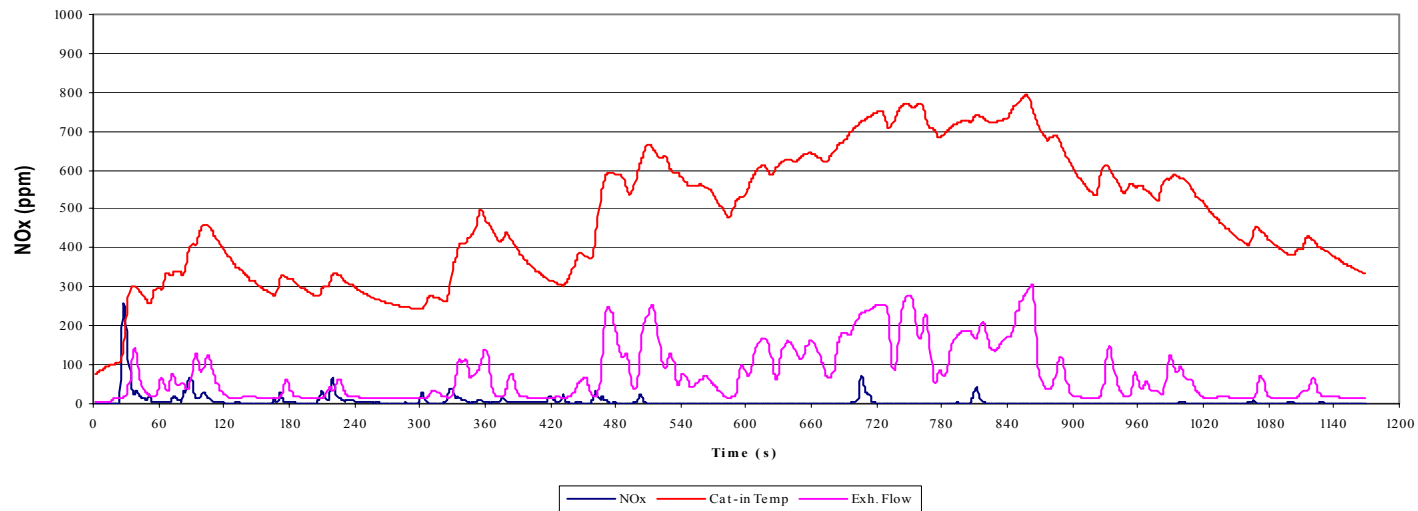
NEX Hot Transient NO_x Analysis



Production Cats - Cat-out NO_x, Exh. Flow, Cat-in Temp vs Time



NEX Alabama Cats - Cat-out NO_x, Cat-in Temp, Exhaust Flow vs Time



600 cpsi NEX Advanced Cats

Comparison with baseline

Test Description	THC g/bhp.hr	CH4 g/bhp.hr	NMHC g/bhp.hr	CO g/bhp.hr	NOx g/bhp.hr	NOx+NMHC g/bhp.hr
Production Converters 125 hrs CNG hot runs average	0.36	0.345	0.015	1.04	0.202	0.217
Advanced Cats NEX 311H1 30G 600 cpsi 125 hrs CNG hot runs average	0.101	0.095	0.006	0.931	0.08	0.086
Emissions Reductions	72%	72%	60%	11%	61%	61%

NEX Advanced Catalyst Best Performance

Useful life emissions vs Standards

Test Description	THC g/bhp.hr	NMHC g/bhp.hr	CO g/bhp.hr	NOx g/bhp.hr	NOx+NMHC g/bhp.hr
Advanced Catalysts Best performance to date 125 Hr Converters CNG hot runs average	0.101	0.006	0.931	0.08	0.086
EPA Assigned DFs	1.9	2.2	1.6	1.3	
Useful Life Emissions CNG	0.1919	0.0132	1.4896	0.104	0.1172
CARB Emissions Standards LEV II 05 SULEV			7.2		0.5
2007 and later Standards		0.14	7.2	0.2	

Conclusions on Phase I Engine Research



- The project has shown that advanced calibration/catalyst systems can provide the opportunity for a certifiable engine package which meets the MY 07 heavy duty standards today.
- This is PZEV territory, with NO_x levels 1/20th LEV I SULEV
- NO_x emissions have been reduced 60%, and methane emissions have also been significantly reduced by 72%
- Brake specific fuel economy remains unchanged with advanced calibration/catalyst systems
- Cost impact of advanced catalyst is expected to be minimal

NGNGV Phase II

Phase II CNG Vehicle Development Plan:

**Development of a GM 8.1L Low NOx CNG engine, and
integration into a commercially viable chassis**

ENGELHARD



ARBOC ASG Renaissance

Objectives



- Develop a low NO_x GM 8.1 L dedicated CNG engine and certify it to EPA and CARB MY 2007 heavy duty emissions standards of 0.2 g/bhp.hr NO_x, and 0.01g/bhp.hr particulate matter
- Fully integrate the engines into commercially viable chassis applications, based on the GM 560 cutaway chassis
- Conduct fleet trials in commercial service, evaluate real world performance and refine as required
- Commercialize the vehicle



Project Team

Teleflex GFI Control Systems Inc

- Project management, Engine development
- Team coordination

General Motors

- Engines, vehicles, engineering support

Engelhard Corporation

- Supply of advanced catalysts, Technical support

➤ ARBOC Ltd.

- Vehicle Integration, Field Data, customer feedback

➤ ASG Renaissance

- Identification and implementation of Demonstration Fleet

EngineTechnology



- Fuel system technology will build on the existing GM T-610 6.0 L CNG system
- 8.1 L engine will use:
 - Same PCM and software
 - Siemens injectors
- Emission control technology will build on advanced catalyst technology developed under the Phase I Low NOx GM 6.0 L CNG engine development

Vehicle Integration



Two vehicle integration activities are planned:

- Low floor bus (supported by NREL)
- Cab and Chassis (under consideration for support by SCAQMD)

Vehicle Integration



Low floor bus:

Develop a low floor derivative of the GMT 560 Cutaway based on the proprietary ARBOC Low Floor Rear Drive technology that permits bus configurations that comply with ADA access without a wheelchair lift. The vehicle will be powered by the low emission 8.1L CNG engine, integrated into the low floor bus design

Cab and Chassis:

Integrate the low emission CNG fuel system into a GMT 560 cab and chassis which can be used in a variety of vehicle applications



Demonstration Fleet

For both low floor bus and cab and chassis applications:

ASG will work closely with a fleet to identify a good application for the vehicles and to conduct on-road testing of the vehicles during the standard operation of the fleet.

Comparator vehicles will be part of the existing fleet

The vehicle will be integrated into a revenue fleet for the purpose of testing and collecting data for a minimum of six months of operation.



Demonstration Fleet

Driver, operation, and maintenance training for the selected fleet personnel will be provided

- Technician training or on-site service at cost through a local GM dealer will be provided
- Make vehicle available to NREL at the completion of the fleet demonstration for chassis testing on the West Virginia University dynamometer.

Timing



- Product introduction during MY 05
- Two year program commencing 2003
 - Engine development and certification – 1 year
 - Vehicle integration and field testing - 1 year

Livestock is still used for transportation



Traction Control Problems

How Much Brown Cow



- **“Chewing the cud yields enormous amounts of flammable methane that should, in theory, make cattle vulnerable to unexpected ignition”**
- **A single cow exhales about 600 litres of methane every day**
- **Applying EPA assigned emissions deterioration factors, this amounts to useful life emissions of over 80 kg per year CH₄, compared with the humble NGV producing about 4kg CH₄ per year**
- **There are about 2 million NGV’s worldwide, compared with 1.3 billion large ruminating animals, so there is really no contest in methane production**

Livestock dramatically outperforms NGV’s in making methane